DTI OF THE HUMAN KIDNEY: DOES IMAGE CO-REGISTRATION PERMIT NON-TRIGGERED SCANNING?

Maryam Seif[1], Huanxiang Lu[2], Chris Boesch[1], Mauricio Reyes[2], and Peter Vermathen[1]

[1]*Depts Clinical Research and Radiology, University Bern, Bern, Switzerland,* [2]*Institute for Surgical Technology and Biomechanics, University Bern, Bern, Switzerland*

Background: Recently there have been several studies performing diffusion tensor imaging (DTI) in abdominal organs including human kidney[1-4]. DTI holds promise to assess kidney function and combines functional information on diffusion and potentially micro-perfusion properties with additional structural information. However abdominal DTI is very sensitive to motion artifacts[1] caused by respiration, leading to phase misregistration, blurring and signal void. In order to reduce severe physiological motion artifacts, DTI scans are commonly performed either during a breath-hold period or employing respiratory triggering methods. Nevertheless, even in triggered scans residual motion artifacts remain. Previously we have demonstrated that in triggered scans, non-rigid image co-registration of individual echo planer DTI images of human kidneys reduces the residual motion artifacts and leads to lower variability of diffusion parameters[5]. **Purpose:** Based on our precedent encouraging results, the aim of the current study was to investigate, if non-rigid image co-registration reduces motion artifacts in non-triggered DTI scans and to determine, if the potential improvement may allow for omitting the time consuming respiratory triggering.

Methods: Eight healthy volunteers (5 female 3 male, age =24.5±3.2y) underwent a DW single shot echo-planar sequence with ten different b-values between 0 and 700 s/mm² in 6 non-collinear directions on a clinical 3T MRI scanner (Siemens Erlangen Germany). The DTI was acquired using the following parameters: acq.=2, TR_{min}=3300ms, TE=66ms with and without respiratory triggering, a minimal acquisition time of 6min. for non triggered and 10.1±3.1 min. for triggered scans. Co-registration of individual images was performed using an in-house developed multimodal non-rigid registration software, based on point-wise mutual information[6]. Further data processing included biexponential fitting, yielding ADC, the perfusion fraction, and calculation of the fractional anisotropy (FA). At least 6 regions of interest (ROI) were placed on several slices for each subject in medulla and cortex with voxel-average of 11±4 and 8±3 respectively. The ROIs were placed carefully and independently for the triggered and non triggered scans as well as for the co-registered and the non co-registered images. The co-registered and original images were compared in two ways as has been done before[5]: 1) For each analyzed ROI, the standard deviation (SD) was calculated from all pixels within the ROIs; 2) The deviation from diffusion-model fitting was determined comparing the root mean squared error (RMSE). RMSE was determined for fitting the signal only for b-values b<100 sec/mm² (RMSElow), for b-values b>100sec/mm² (RMSEhigh), and for fitting all b-values (RMSEtot).

Results: Co-registered ADC and signal intensity (S_0) maps (Fig.1) as well as FA maps (Fig.2) demonstrated visually less distortion and noise artifacts within the kidney. The improvement appeared to be stronger in triggered than in non-triggered scans. The SDs of almost all parameters were lower after co-registration for both, triggered and non-triggered scans, with some differences reaching significance. A significant decrease of RMSEtot ($p<0.05$) was obtained after co-registration for triggered and also for non-triggered scans (Fig.3). Similar findings were obtained for RMSElow and RMSEhigh. RMSEtot of non-triggered scans decreased for each subject after co-registration in medulla and cortex (Fig4). The improvement due to co-registration was more substantial for non-triggered than for triggered scans (Fig. 3). However, triggered scans still demonstrated significantly lower RMSE than non-triggered scans, although the differences become smaller after co-registration.

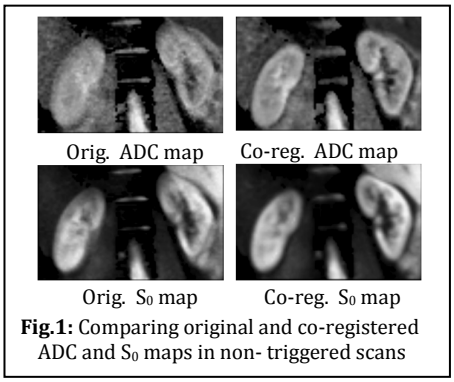

Fig.1: Comparing original and co-registered ADC and S_0 maps in non- triggered scans

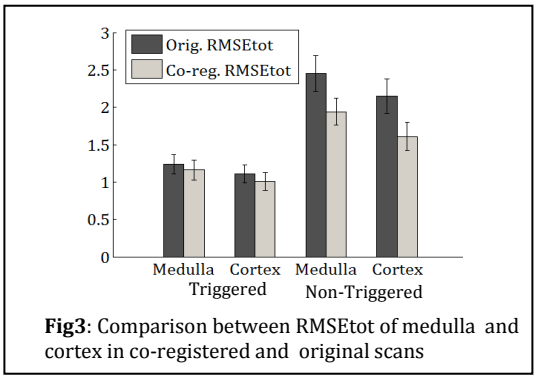

Fig3: Comparison between RMSEtot of medulla and cortex in co-registered and original scans

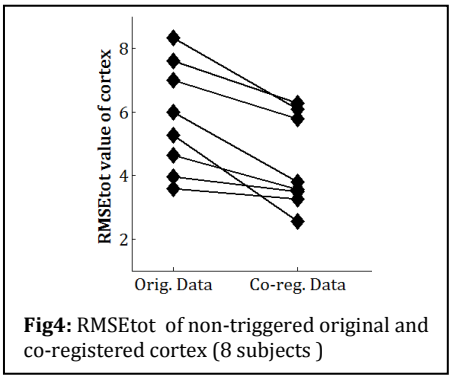

Fig4: RMSEtot of non-triggered original and co-registered cortex (8 subjects)

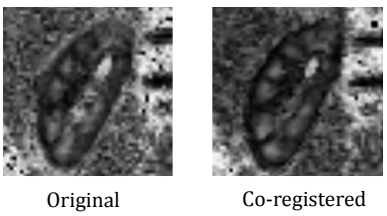

Fig. 2: Comparing non- triggered original and co-registered FA maps

Discussions & Conclusions: The results demonstrated the benefit of co-registration of individual EP-images in renal DTI for both, triggered and especially for non-triggered scans by clearly reduced signal variations. For triggered scans the co-registration improvement was lower than in our previous study[5], which is probably due to a careful (and time consuming) separate ROI placement in the current study for all scans with and without co-registration. Currently the triggered scans have lower variabilities compared to the non-triggered scans, both with and without co-registration and thus triggering method should still be performed for best results. However, the clear improvement especially of non-triggered scans due to co-registration and the consequential smaller difference compared to triggered scans suggest that uncooperative patients as well as other organs or transplanted kidneys, where respiration motion is less severe, may be measured without triggering.

References: **1**. Notohamiprodjo M, et al. Invest. Radiol. 43:677 2008. **2.** Kataoka M, et al. J. Magn Reson. Imaging 29:736 2009 **3.** Cutajar M, et al. Eur. J. Radiol. 80:E263 2011. **4**. Sigmund EE, et al. Radiology263:758. 2012. **5.** P. Vermathen et al. ISMRM 2577 2011. **6.** Lu H, et al. ISBI 372 2010.